Chapter 8

CONSERVATION

This chapter presents module descriptions for the conservation component of a CTSA, including the following modules:

- Energy Impacts.
- Resource Conservation.

Businesses are finding that by conserving energy and resources they can cut costs, improve the environment, and improve their competitiveness. Energy use and resource consumption may be significant factors in evaluating alternatives. Data from both of these modules are considered in the Social Benefits/Costs Assessment and Decision Information Summary modules along with risk data, traditional competitiveness information (e.g., regulatory status, performance, and cost), and other information.

The Energy Impacts module may involve assessing energy consumption both during chemical manufacturing and during process operation. This is used to compare energy uses of the baseline and substitutes. The Resource Conservation module includes evaluating the amount of materials currently used in the process (renewable and nonrenewable resources) and the effects substitutes would have on resource use. Both of these modules use the Performance Assessment module as a key data source.

ENERGY IMPACTS

OVERVIEW: Energy consumption, either during the manufacture of a chemical or the use of a product, process, or technology can vary with a selected chemical or process change. The Energy Impacts module describes methods for evaluating the energy impacts of the baseline and substitutes within a use cluster. In a CTSA, data on the energy impacts of the baseline and substitutes are usually collected in the Performance Assessment module.

GOALS:

- Determine the energy requirements of the baseline and of the substitutes.
- Evaluate the relative energy impacts of the baseline as compared to the substitutes.
- Provide data on energy requirements and relative energy impacts to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- Familiarity with sources and rates of energy consumption (e.g., equipment) in the use cluster.
- Ability to perform simple energy calculations involving power ratings (kW or BTU/hr), duty (hr/day), and equipment load (percent of rated power used during equipment operation).

Within a business or DfE project team, the people who might supply these skills include a plant engineer, environmental engineer, line supervisor, line operator, or equipment vendors.

DEFINITION OF TERMS:

British Thermal Unit (BTU): The quantity of heat required to raise the temperature of one pound of water from 60 to 61 ^{o}F at a constant pressure of one atmosphere.

Duty: Period of time equipment is operated under powered conditions (e.g., lights may be utilized for 16 hrs/day).

Horsepower (hp): The predominant English unit of power used to describe motor ratings in the U.S. In the metric system the usual measure of power is Joules/hr. One hp = 42.43 BTU/min = 2.7×10^6 Joules/hr = 0.7457 kilowatts (kW).

Kilowatt Hour (kWh): One kWh is the quantity of energy converted or consumed in 1 hour at the constant power rate of 1 kW. One kWh is equivalent to 3413 BTU.

Load: A factor reflecting the actual power used by a piece of equipment relative to the design power rating. For example, an electric motor may be oversized and draw only 80 percent of its nominal power rating when operating a specific piece of equipment.

Nominal Power Rating: The nominal energy use rate of energy consuming equipment operating under design conditions (e.g., an electric motor may have a power rating of 1 hp).

APPROACH/METHODOLOGY: The following presents a summary of the technical approach or methodology for evaluating the energy impacts of substitutes. Methodology details for Steps 3, 4, and 6 follow this section.

Step 1: Review the Chemistry of Use & Process Description module to identify pieces of equipment that consume energy in the baseline or the substitutes. Note equipment that would be added or deleted, depending on the substitute. Examples of specific pieces of equipment which consume energy include drive motors, air fans, direct resistance heating elements, refrigeration system compressors, and natural gas-fired ovens.

Step 2: Review the Control Technologies Assessment module to identify the control technologies that are recommended or required for the baseline or the substitutes. This can include air pollution control technologies, chemical destruction technologies (e.g., incineration, etc.) as well as in-plant waste water treatment technologies. The energy consumption of control technologies should also be evaluated, particularly if a control technology is required to meet environmental regulations.

Step 3: Based on the equipment identified in Steps 1 and 2, determine the data required to evaluate the rates of energy consumption of the baseline and of the substitutes. Provide data requirements to the Performance Assessment module so that energy consumption data can be collected during the performance demonstration project. For each piece of energy using equipment, typical data requirements include:

- The nominal power rating.
- The average duty.
- The average load.
- Production capacity/through-put (e.g., parts/hr, ft^2 processed/day).

Data should be collected on a per unit production basis, or some other basis that allows a comparative evaluation of the energy trade-off issues.

Step 4: Obtain data from the Performance Assessment module and calculate the energy requirements of the baseline and of the substitutes. Again, energy requirements should be calculated on a common basis to allow for a comparative evaluation of the substitutes.

Step 5: Provide the energy requirements for the baseline and the substitutes to the Cost Analysis module. The cost of energy usages can be obtained from supplier (e.g., electric utility, natural gas utility) rate schedules.

Step 6: If up-stream energy impacts are being evaluated in the CTSA, review the Chemical Manufacturing & Product Formulation module to evaluate energy requirements during the manufacturing of chemical ingredients or the formulation of chemical products. CTSA pilot projects have qualitatively evaluated up-stream energy impacts.

Step 7: Tabulate energy requirements calculated in Step 4 together with data on up-stream energy impacts from Step 6 to evaluate the relative energy impacts of the baseline as compared to the substitutes.

Step 8: Report the relative energy impacts of the substitutes to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

METHODOLOGY DETAILS: This section presents methodology details for completing Steps 3, 4, and 6. If necessary, additional information on this and other steps can be found in previously published guidance.

Details: Step 3, Collecting Data on Energy Consumption

Data for each substitute should be collected for a consistent unit process, such as the time to complete the function defined by the use cluster one time. This facilitates a comparative evaluation of the substitutes. The following summarizes sources of nominal power rating, duty, and load data:

- The nominal power rating is usually displayed on an identification plate on the equipment (e.g., a pump motor nameplate may read 1.0 hp). In some cases where nameplate data are unavailable, power ratings may be obtained from the manufacturer's literature or from equipment vendors.
- Duty can be measured using a simple timer or estimated by the equipment operator. Again, duty should be measured for a consistent process (e.g., the time a pump is required to dispense a solvent when cleaning ten 3,200 in^2 printing screens).
- Electric load can be calculated from the average current amperage and the supply voltage (e.g., average current amperage multiplied by supply voltage yields average electric power in kW). The average current amperage can be measured with an electric current (amp) meter. Gas use can be measured with gas metering equipment or it can be estimated by knowledgeable plant personnel.

If performance data are being collected from existing sources instead of tests performed as part of the CTSA, estimates of energy usage data can be obtained from equipment vendors or other sources.

Details: Step 4, Calculating Energy Requirements

Depending upon the particular circumstances, the method for calculating energy use will vary. For example, if each piece of energy consuming equipment in a process is unique and the required data can be readily collected (for example, with a dedicated power meter), the electrical energy consumption rate can be estimated using the following formula:

Net Energy Consumption (energy use/time)
= (No. pieces of equipment) x (power rating/unit) x (average duty) x (load)

Example: A coolant system for a machining operation requires 2 pumps to supply the operation with coolant liquid. The characteristics and operating parameters of each pump are as follows:

pump power rating	= 10 hp
average duty	= 8 hours/day
estimated operating load	= 80 percent

Thus, the estimated net energy consumption for the coolant pumping operation is calculated as:

Net Energy Consumption (kWh/day)
= (2 pumps) x (10 hp/pump) x (1 kW/0.746 hp) x (8 hours/day) x (0.80)
= 172 kWh/day

For equipment using natural gas, the net energy consumption may be given by:

Net Energy Consumption (BTU/day)
= (rating in BTU/hr) x (hours/day duty) x (load)

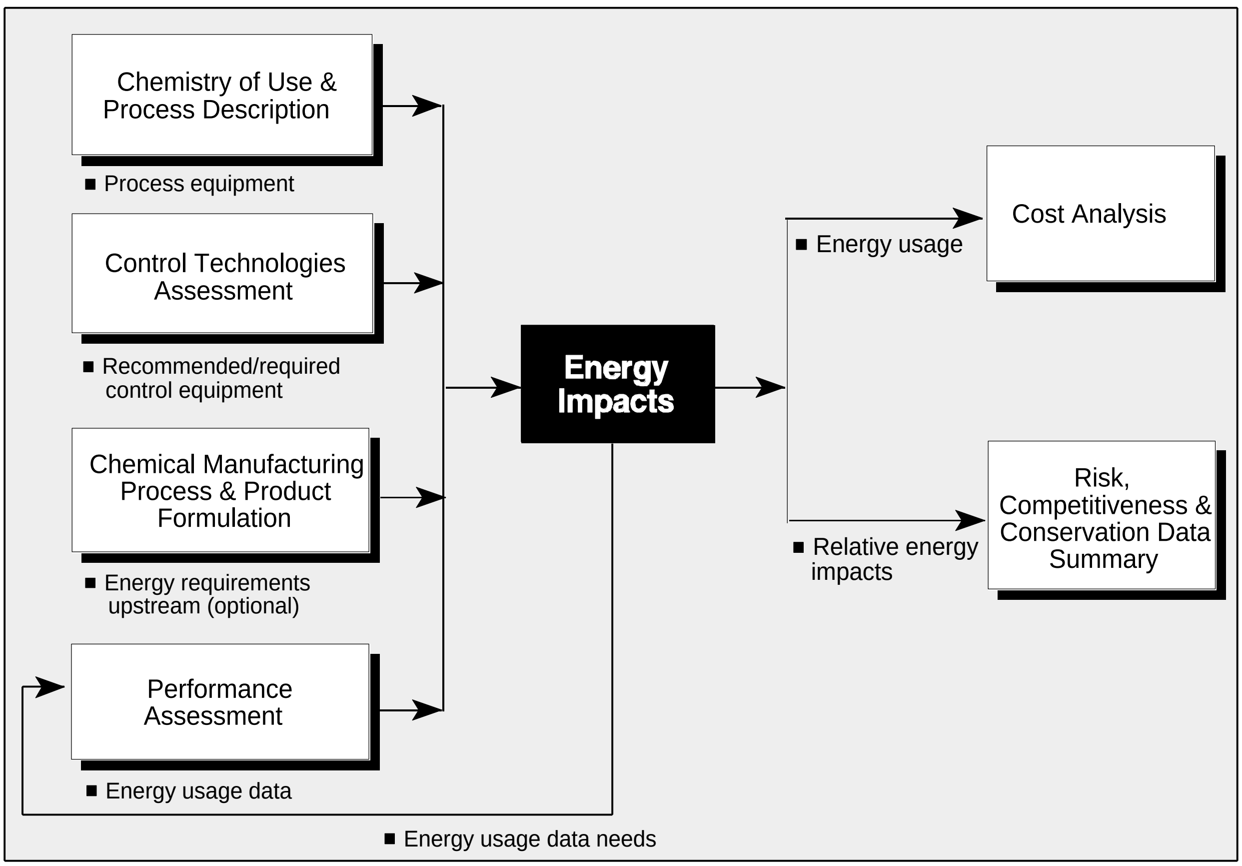
Details: Step 6, Evaluating Up-stream Energy Impacts

The following are examples of the types of questions a DfE project team might consider when qualitatively evaluating up-stream energy impacts:

- Are chemical ingredients made from raw materials that have an energy equivalence (e.g., petroleum-based chemicals versus vegetable-based)?
- Under what types of reactor conditions are chemical ingredients manufactured (e.g., what is the reactor temperature, pressure, and retention time)?
- Is the chemical formulation a simple mixing process? Does it involve chemical reactions between the formulation ingredients? Are heat or pressure required to get chemical ingredients into solution?

FLOW OF INFORMATION: Data requirements for the Energy Impacts module are identified based on information from the Chemistry of Use & Process Description, Control Technologies Assessment, and Chemical Manufacturing Process & Product Formulation modules and collected in the Performance Assessment module. (The energy impacts of up-stream processes, such as chemical manufacturing or product formulation, could be collected from suppliers during a performance demonstration project. Up-stream energy impacts have not been quantitatively evaluated in DfE pilot projects, however.) The Energy Impacts module transfers data to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules. Example information flows are shown in Figure 8-1.

FIGURE 8-1: ENERGY IMPACTS MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODELS: None cited.

PUBLISHED GUIDANCE: Table 8-1 presents references for published guidance on estimating energy consumption for process equipment and performing energy audits.

TABLE 8-1: PUBLISHED GUIDANCE ON ENERGY ASSESSMENTS

Reference	Type of Guidance
Smith, Craig B. 1981. *Energy Management Principles, Applications, Benefits, and Savings.*	Methods for performing energy audits and calculating energy consumption for process equipment.
Thumann, Albert. 1979. *Handbook of Energy Audits.*	Methods for performing energy audits and calculating energy consumption for process equipment.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: Table 8-2 lists sources of energy consuming equipment data.

TABLE 8-2: SOURCES OF ENERGY CONSUMPTION DATA

Reference	Type of Data
American Council for an Energy-Efficient Economy. 1991. *Energy-Efficient Motor Systems.*	Methods for determining energy consumption and efficiency for various types of electric motors.
Garay, Paul N. 1989. *Pump Application Desk Book.*	Methods for determining energy consumption and efficiency for various liquid pumping systems.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

RESOURCE CONSERVATION

OVERVIEW: Resource conservation is the process of selecting and using products, processes, or technologies that minimize the overall use or consumption of resources while effectively achieving a desired function. The Resource Conservation module describes methods for identifying the relative amounts of resources or materials used or consumed by a business as a consequence of changing from a chemical, process, or technology to a substitute. In a CTSA, resource consumption data are usually collected in the Performance Assessment module.

The methods described here focus on direct resource use rates (e.g., the amount of materials consumed to manufacture a product), *not* indirect resource use rates (e.g., the amount of land that is consumed by landfilling waste). Indirect resource consumption is qualitatively evaluated in the Social Benefits/Costs Assessment module.

GOALS:

- Determine the relative amounts of resources consumed by the baseline and the substitutes.
- Evaluate the relative effects on resource conservation of the baseline as compared to the substitutes.
- Provide data on resource consumption rates and relative impacts to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- Familiarity with the types, sources, and supply of resources consumed by the baseline and substitutes.
- Familiarity with the common operating practices employed by the industry that might affect the rate of resources consumption.

Within a business or a DfE project team, the people who might supply these skills include a plant engineer, material scientist, environmental engineer, line operator, or suppliers of the substitutes.

DEFINITION OF TERMS:

<u>Natural Resources</u>: Material or substance which in its basic form is found in nature. For example, water, petroleum, and wood are natural resources in the sense that they do not have to be made in an industrial process.

Renewable Resource: As defined in Society of Environmental Toxicology and Chemistry publications, a renewable resource is one that is being replenished at a rate greater than or equal to its rate of depletion. For example, wood used to make paper can be replaced with wood supplied by the growth of new trees as long as the rate of paper production combined with the rate of wood consumption does not exceed the rate of replenishment.

Resource: Material or substance used as a process raw material or required for process operation (e.g., oil for machine lubrication or a chemical feedstock for a chemical reactor).

APPROACH/METHODOLOGY: The following presents a summary of the technical approach or methodology for evaluating the potential impacts of substitutes on resource conservation. Further methodology details for Steps 1, 3, 6, and 7 follow this section.

Step 1: Review the Chemistry of Use & Process Description module to identify the types of resources consumed and the specific process steps where resources are consumed by the baseline and by the substitutes. It may be useful to categorize resources (e.g., chemical products, water, renewable vs. nonrenewable, etc.) to facilitate the evaluation of the relative impacts of alternatives in Step 7. *(Although energy may be derived from renewable and nonrenewable resources, this module does not focus on energy consumption, which is addressed in the Energy Impacts module.)*

Step 2: Review the Control Technologies Assessment module to identify the control technologies that are recommended or required for the baseline or the substitutes. This can include air pollution control technologies, chemical destruction technologies, and in-plant waste water treatment technologies. Evaluate the control technologies to identify the types of resources they consume (e.g., chemical flocculants used in waste water treatment).

Step 3: Determine the data required to evaluate the rates of consumption of the resources identified in Steps 1 and 2. Provide the data requirements to the Performance Assessment module so that resource consumption data can be collected during the performance demonstration project. Data should be collected on a per unit production basis, or some other basis that allows a comparative evaluation of the resource impacts. If performance data are being collected from existing sources instead of tests performed as part of the CTSA, estimates of resource consumption can be obtained from equipment vendors, industry representatives, or other sources.

Step 4: Obtain data from the Performance Assessment module and calculate the resource requirements of the baseline and of the substitutes. Resource requirements should be calculated using a common basis, such as a per unit production basis or the amount of solvent required to perform a cleaning function one time. This facilitates a comparative evaluation of the substitutes.

Step 5: Provide the resource requirements calculated in Step 4 to the Cost Analysis module, where consumption rates will be converted into monetary values.

Step 6: If up-stream resource conservation impacts are being evaluated in the CTSA, review the Chemical Manufacturing Process & Product Formulation module to evaluate resource requirements during the manufacturing of chemical ingredients or the formulation of chemical products. CTSA pilot projects have qualitatively evaluated up-stream resource conservation impacts.

Step 7: Tabulate resource requirements in Step 4 together with data on up-stream resource consumption from Step 6. Evaluate the relative impacts on resource conservation of the baseline as compared to the substitutes.

Step 8: Report the results of the evaluation to the Cost Analysis and Risk, Competitiveness & Conservation Data Summary modules.

METHODOLOGY DETAILS: This section presents methodology details for completing Steps 1, 3, 6, and 7. If necessary, additional information on this and other steps can be found in the published guidance.

Details: Step 1, Categorizing Resources

To simplify the process for evaluating the relative impact of substitutes on resource conservation, it is useful to develop a means of categorizing similar resources. For example, different chemical products used in one or more process steps could be categorized together, as could water resources, or process materials such as lubricating oils. Table 8-3 gives an example of categorizing the resources consumed during a three-step process to clean manufacturing equipment.

In this example, the equipment is cleaned with a chemical cleaning product; the resources consumed are water, chemicals, and the machine oil necessary to lubricate the cleaning equipment. After cleaning, the cleaned equipment is rinsed with water; process materials are also consumed in this step as the manufacturing equipment degrades incrementally with each cleaning, until it must be replaced. In the final step, some amount of trial processing is required after the cleaning, which results in finished products that do not meet specifications and must be discarded. The two resources consumed in this step are the waste product from the run and the machine oil that is used to lubricate the equipment.

TABLE 8-3: EXAMPLE OF CATEGORIZING SIMILAR RESOURCES				
Process Step	**Resources**			
	Water	**Chemical Products**	**Final Product Materials**	**Process Materials**
Step 1 - Cleaning	Dilute chemical product with water	Chemical cleaning product	None	Machine oil to lubricate cleaning equipment
Step 2 - Rinsing	Water rinse	None	None	Manufacturing equipment depleted after x cleanings
Step 3 - Waste Run	None	None	Trial processing after cleaning to achieve acceptable quality	Machine oil to lubricate manufacturing equipment

Details: Step 3, Collecting Data on Resource Consumption Rates

Data on resource consumption rates can be estimated based on purchase (inventory) records, process operator judgement, vendor data, or measured directly. Whichever technique is used, resource consumption data should be collected or converted into consistent units for the baseline and the substitutes, usually in unit mass (pounds or kilograms) per unit time or unit production. The following are examples of different types of data that can be used to estimate resource consumption rates.

<u>Example, Using Existing Records</u>

For the example of using purchase records to estimate the amount of plastic used in a plastic extrusion operation:

- Records show that 2,500 lbs of plastic pellets are purchased each year.
- It is estimated by the process specialist that 40 percent of this amount is used in the specific process under review.
- (0.40) (2,500 lbs/year) = 1,000 lbs used per year in process.

For the example of using purchasing records to estimate the amount of paint used in a parts painting operation:

- A potential substitute is a technology change where an improved paint spray system with a higher application efficiency will be utilized.
- It is estimated from case study data that a 35 percent reduction in paint use will be achieved since overspray losses will be substantially reduced with the use of the new system.
- From purchasing records it is calculated that 20,000 lbs of paint are currently purchased annually.

- The reduction in raw material (resource) use is estimated as:
  (20,000 lbs per year) - ([1-0.35] x [20,000 lbs per year]) = 7,000 lbs per year.

Example, Using Direct Measurement

For the example of using direct measurement to determine the amount of water utilized per year in a continuous flow rinse tank operation:

- Divert water flow from tank inlet into a container of known volume.
- Collect liquid until 1.5 gallon container is full (determine time interval using a stopwatch).
- Determine amount of time rinse tank is utilized per year.
- If it takes 5 minutes to collect 1.5 gallons, and the tank is used 8 hours/day, 5 days/week, 52 weeks/year:

  Water Consumption Rate = (1.5 gal/5 min) (60 min/hr) (8 hr/day) (5 day/wk) (52 wks/yr) = 37,440 gallons/yr

  Converting to lbs/yr:

  Water Consumption Rate = (37,440 gal/yr) x (8.34 lbs/gal) = 312,249 lbs/yr

Details: Step 6, Evaluating Up-stream Resource Conservation Impacts

The following are examples of the types of questions a DfE project team might consider when qualitatively evaluating up-stream resource conservation impacts:

- Are chemical products made from renewable or nonrenewable resources?
- Are scarce resources consumed to manufacture the chemicals or technologies in the use cluster?
- Are the raw materials used to manufacture the substitutes only found in low concentrations in their natural state (e.g., metals only in low concentrations in their ores)?

Details: Step 7, Evaluating the Impacts on Resource Conservation

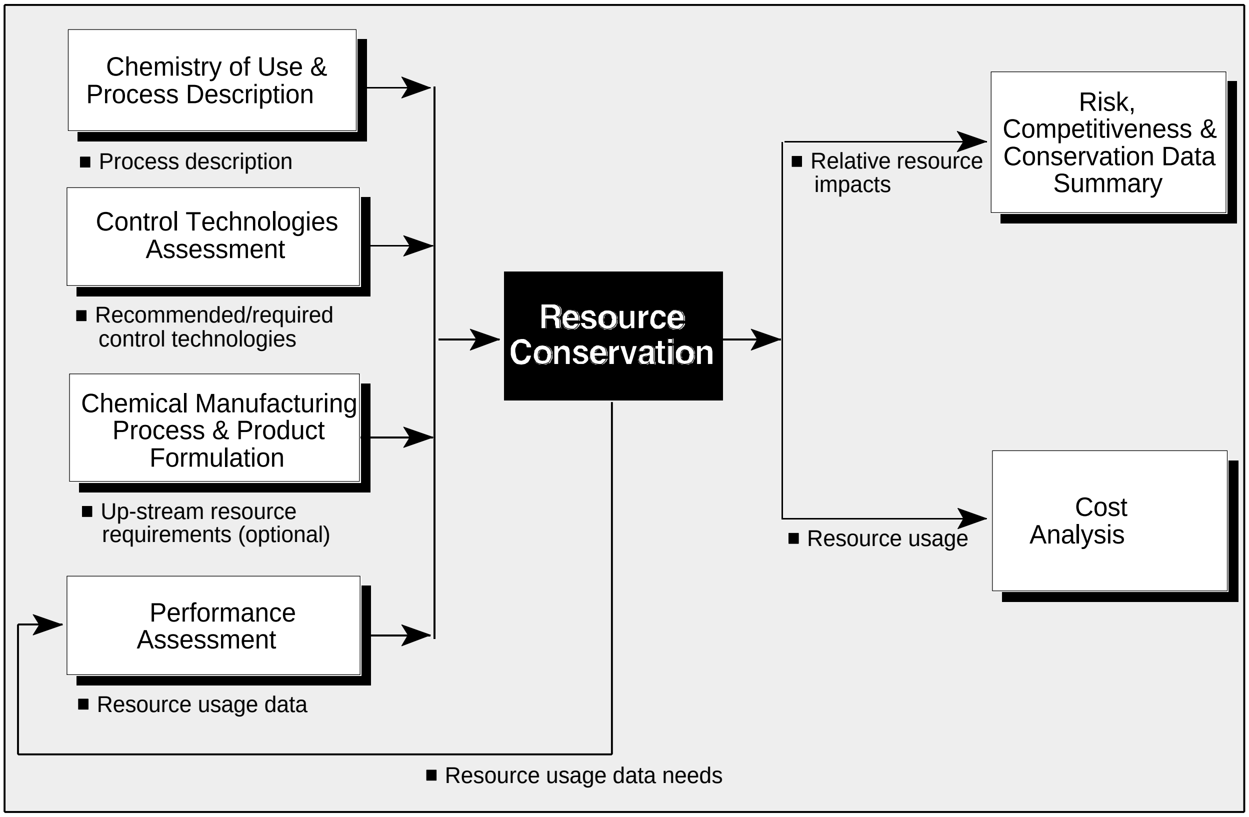
Tabulate the types and quantities of resources consumed by each substitute and baseline technology. Use the tabulation to determine if use of a substitute would result in a relative increase or decrease in overall resource consumption for similar categories of resources. The table may also be used to determine if renewable resources are being substituted for nonrenewable ones or if scarce resources are being substituted for resources in abundant supply. For the example above (see Table 8-3), Table 8-4 gives an example format for tabulating consumption rates.

TABLE 8-4: EXAMPLE OF TABULATED RESOURCE CONSUMPTION DATA FOR ONE SUBSTITUTE							
Process Step	**Resource**						
	Water	**Chemical Product**		**Waste Product**		**Process Materials**	
	Rate (gallons/hr)	**Rate (lb/hr)**	**Renewable**	**Rate (lb/hr)**	**Renewable**	**Rate (amt/time)**	**Renewable**
Step 1 - Cleaning	1	10	yes[a]	N/A	N/A	1 lb/shift	no
Step 2 - Rinsing	100	0	N/A	N/A	N/A	2 sets/yr	no
Step 3 - Waste Run	0	0	N/A	5	no	1 lb/shift	no
TOTAL	101	10	----	5	----	2 lb/shift of oil 2 sets equipment/yr	

N/A: Not applicable.
a) A citrus oil-based cleaner might be an example of a cleaner made from renewable ingredients. (However, petrochemicals are frequently used in the manufacture of chemicals made from vegetable products.)

FLOW OF INFORMATION: Data requirements for the Resource Conservation module are identified based on information from the Chemistry of Use & Process Description, Control Technologies Assessment, and Chemical Manufacturing Process & Product Formulation modules and collected in the Performance Assessment module. (The resource impacts of up-stream processes, such as chemical manufacturing and product formulation, could be collected from suppliers during a performance demonstration project. Up-stream resource conservation impacts have not been quantitatively evaluated in DfE pilot projects, however.) The Resource Conservation module transfers data to the Risk, Competitiveness & Conservation Data Summary and Cost Analysis modules. Example information flows are shown in Figure 8-2.

FIGURE 8-2: RESOURCE CONSERVATION MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODELS: None cited.

PUBLISHED GUIDANCE: Table 8-5 presents published guidance on estimating the rates of resource consumption.

TABLE 8-5: PUBLISHED GUIDANCE ON ESTIMATING RESOURCE CONSUMPTION

Reference	Type of Guidance
Brown, Lisa, Ed. 1992. *Facility Pollution Prevention Guide.*	General methods for identifying and quantifying process materials consumption.
Dally, James W., et. al. 1984. *Instrumentation for Engineering Measurements.*	Methods for analyzing waste stream and raw material input quantities are discussed in cases where physical measurements are required.
Theodore, Louis and Young C. McGuinn. 1992. *Pollution Prevention.*	General description of process analysis.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: Table 8-6 lists sources of data which may be useful in calculating resource consumption rates.

TABLE 8-6: SOURCES OF DATA ON RESOURCE CONSUMPTION RATES

Reference	Type of Data
Bolz, Ray E. and G.L. Tuve. 1970. *Handbook of Tables for Applied Engineering Science.*	Contains data which may be useful in analysis, such as material densities.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.